تعريفات هامة

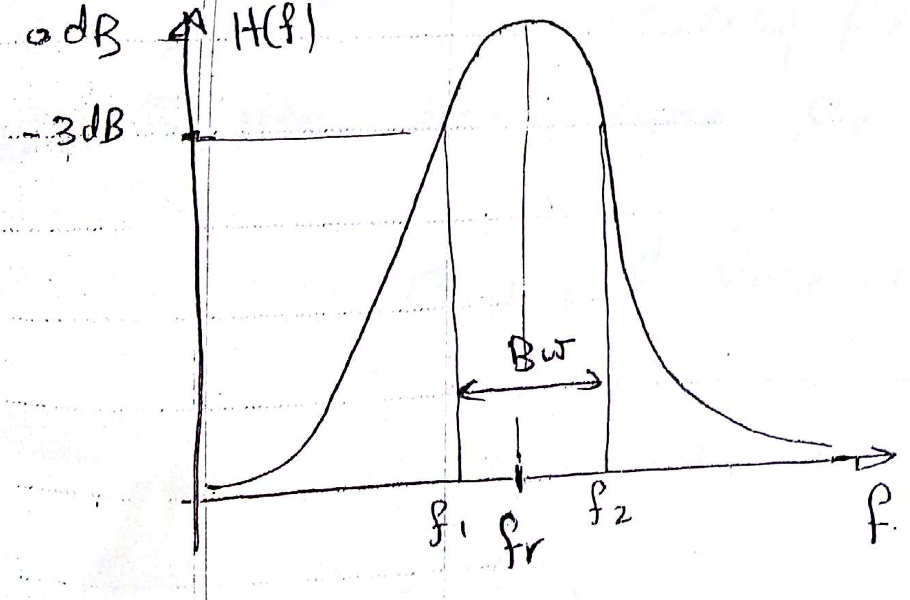
1) Selectivity: ⇒ the ability of the receiver to reject the unwanted signals.

* Selectivity is obtained by using Tuned Circuits and filters

  * As the No of filters increase the selectivity incre
  * As The Quality factor Q increase " " " "

$Q \uparrow\uparrow \longrightarrow$ Selectivity $\uparrow\uparrow$

* the Bw of the Tuned circuit must be wide ~~enou~~ enough to pass the signal and it's sidebands, and narrow enough to eliminate the unwanted signals



$$Bw = f_2 - f_1$$

$$Bw = \frac{f_r}{Q}$$

2] Sensitivity

the ability of the Rx to sense
and amplify the weak signals.

* the higher the amplifier gain the high the Rx selectivity

* High gain reciever is obtained by using multiple amplification stages

types of Receivers

1. Crystal Receiver
2. tuned Radio Frequency Rxs
3. Super heterodyne Rxs

1] Crystal Receiver

هو ابسط أنواع ال Rx AM وبيتكون من

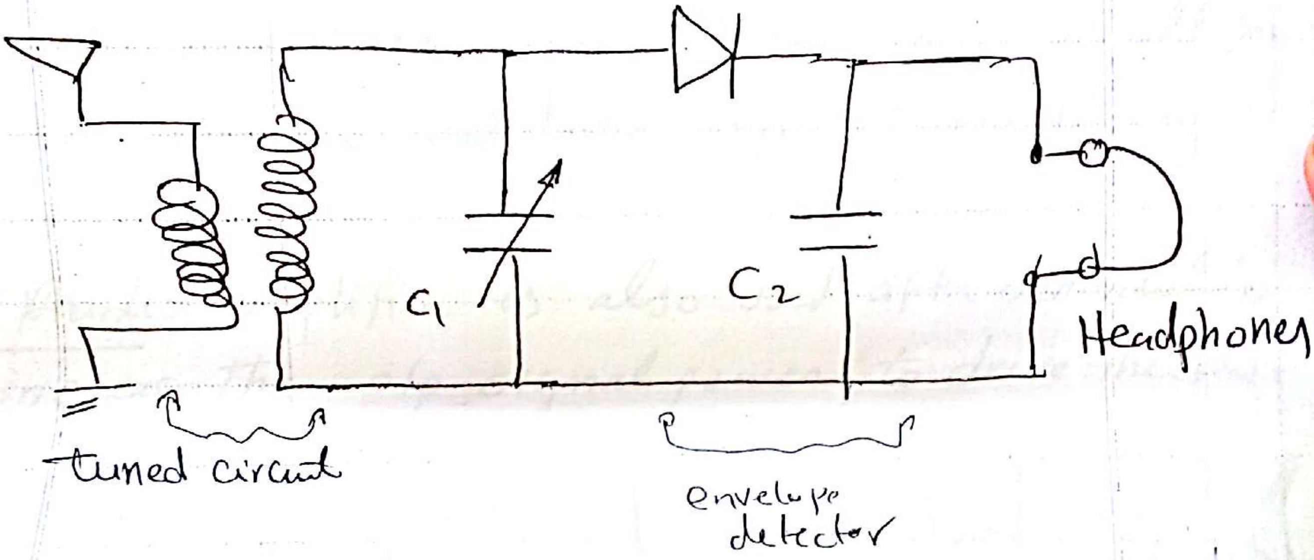
1] tuned circuit :
which provide the selectivity such that the Rx Can separate the desired signals from the unwanted signals

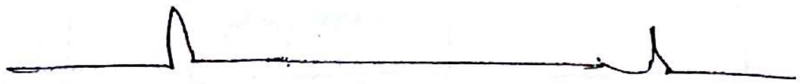
② envelope detector:

Consist of Diode ((Crystal)) and Capacitor

Serve as AM DeModulator

3) earphone ; to reproduce the recoved audio signals.





(2) Tuned Radio Frequency (TRF) Receiver

وهو نظام أحدث من النظام السابق حيث أن النظام السابق

يعاني من بعض العيوب وهي

① low sensitivity ⟹ No Amplifier

② poor selectivity ⟹ only one tuned Circuit

ولحل تلك المشاكل تم عمل (TRF) Rx حيث تم حل مشاكل

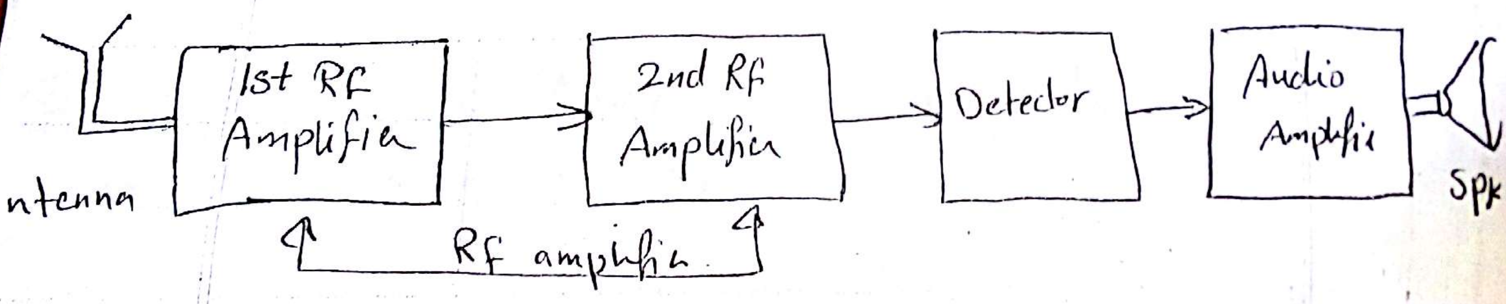
النوع السابق كالتالي

TRF Rx

a) Sensitivity improvement by using groups of RF amplifiers between the antenna and the detector.

* The RF amplifiers stage increase the over all gain of the receiver and hence, improve sensitivity

* An Audio amplifier is also used after demodulator to increase the o/p signal power to drive the speaker

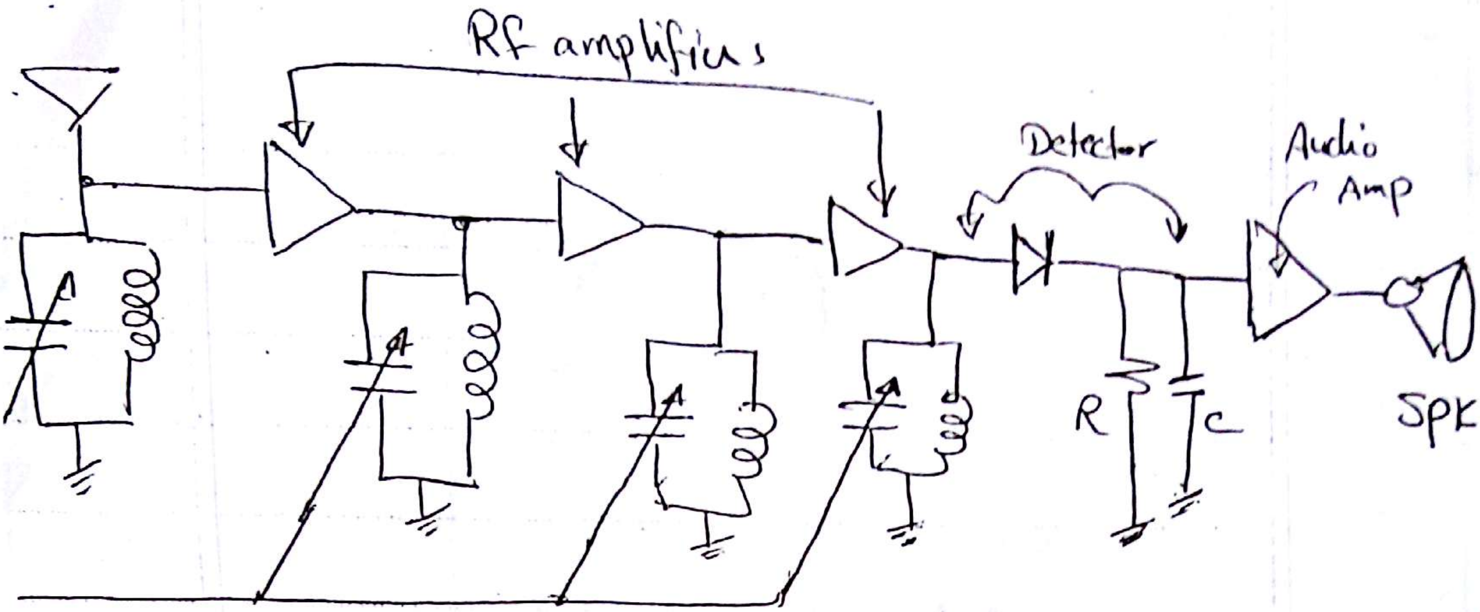


b) Selectivity improvement

⇒ By using multiple tuned circuit with RF amplifiers.

* the greater the tuned circuit the narrower the Band width

* All the tuned circuit are variable to select the desired signal as shown in the figure



Disadvantage of TRF Receiver

① the selectivity of the tuned circuits is vary with the frequency.

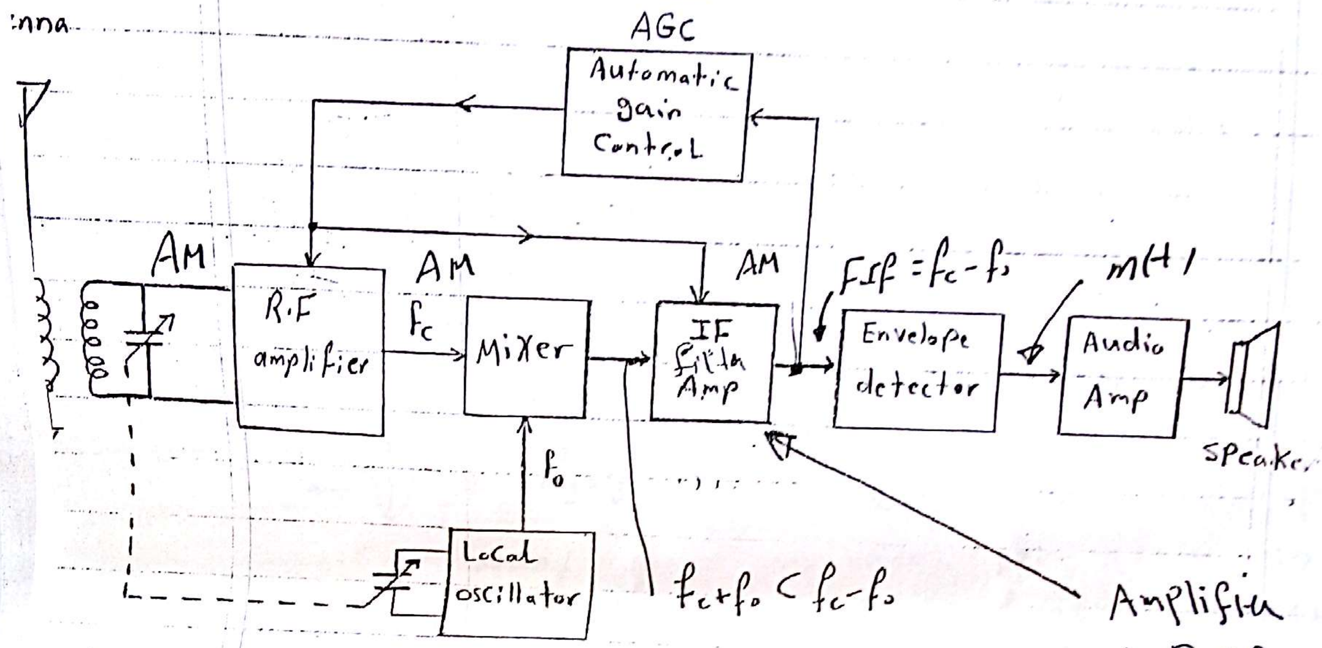
② using multiple tuned circuit may be affect the desired received signal.

3 Super-heterodyne Receiver

في هذا النظام سوف تم التغلب على جميع المشاكل السابقة

* hetro ⇒ تغير translation to another frequency.
dynamis ⇒ تكبير amplification of the detected signal
Super ⇒ from (Super sonic) which means the heterodyn process is above the audio freq. range.

3 Superhetrodyne Receiver Block diagrame



Amplifier + BPF around $f_{IF} = 455KHz$

Main idea of operation :-

- The superhetrodyne receiver takes the incoming radio frequency signals whose frequencies varies from station to another and transform them into a fixed frequency called intermediate frequency (IF). $= F_{IF}$

So that we get fixed receiver performance for all different signals.

تقوم بتحويل ترددات الإشارات المستقبلة (f_{c1}, f_{c2} ,-------, f_{cn}) إلى تردد
واحد فقط ثابت يسمى (f_{IF}) ثم تقوم بعمل الـ demodulation
وذلك لنعطيه نفس الأداء للجهاز لكل المحطات أو الإشارات المستق

Mixer

$$f_{ci} \rightarrow \otimes \rightarrow f_o - f_{ci} = f_{IF} = 455KHz \text{ for AM}$$

f_o متغير حسب المحطة المطلوبة

operation

[1] The antenna Converts the received EM waves into electrical RF signals.

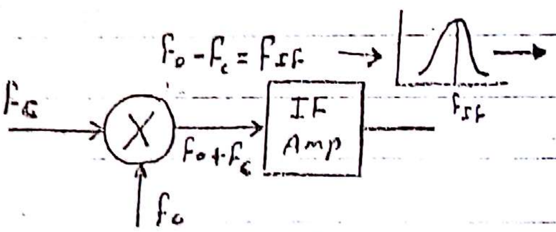
[2] The tuned (LC) RF amplifier is properly tuned by varying the Capacitor value. to select the desired signal, frequency (f_c).

- it also provides sufficient amplification for the radio signal. by RF Amplifier

[3] The Local oscillator frequency (f_o) is tuned by varying the oscillator Capacitor

the oscillator Capacitor is Coupled with the RF amplifier Capacitor, and tuned together at the same time.

[4] mixing →



The received signal frequency (f_c) is mixed with the tuned Local oscillator frequency (f_o) to give a fixed frequency difference Known as intermediate frequency f_{IF}

$$\boxed{f_o - f_c = f_{IF}}$$ تردد ثابت

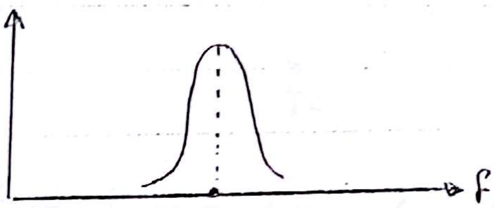
ملاحظة

The mixer o/p will Contain sum and differenc freq, $f_o + f_c$ & $f_o - f_c$

For AM $f_{IF} = 455$ KHZ

5. The IF amplifier is tuned to pass only the difference frequency $(f_o - f_c)$ that equals the $f_{IF} = 455$ kHz.

and reject all other frequencies ($f_o + f_c$ & ~~f_o & f_c~~)



$F_{IF} = 455$ KHz

- The IF amplifier amplifies the signal and provides more selectivity. → مع عرض BW أضيق

6. The output of the IF amplifier is fed to the envelope detector to recover the original signal. « m(t) »

7. The recovered signal is then amplified by the audio amplifier to a level sufficient to drive the Loudspeaker.

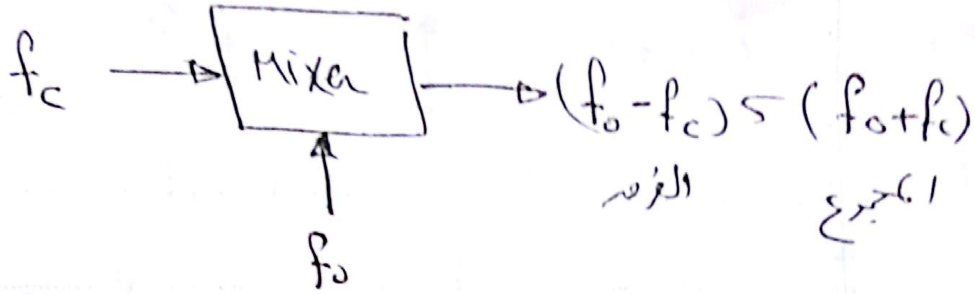
8. AGC →

* the near stations will has high power level while the far or distant stations will has lower power level.

To get fixed power level for all stations we use AGC circuit to adjust the gains of RF and IF amplifiers to provide a signal with fixed power level to the envelope detector.

Mixer operation

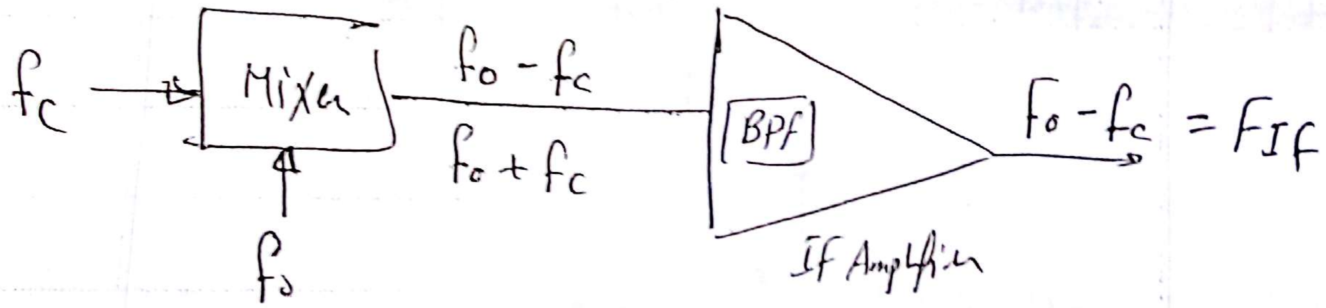
* يقوم الـ Mixer بضرب طلاس تردد الـ f_o ، تردد الـ f_c



* يكون الخرج عبارة عن الفرق $f_o - f_c$ ، حيث $f_o > f_c$ وكذلك المجموع $f_o + f_c$

* IF Amplifier

* يحتوي ع BPF حيث يمرر الفرق فقط



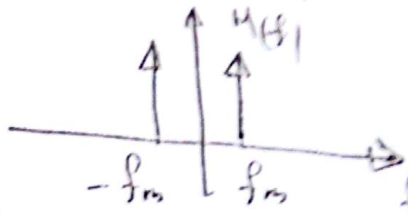
$$\therefore \boxed{\text{IF Amp o/p} = f_o - f_c = F_{IF}}$$

$F_{IF} = 455\ \text{KHz}$ for AM

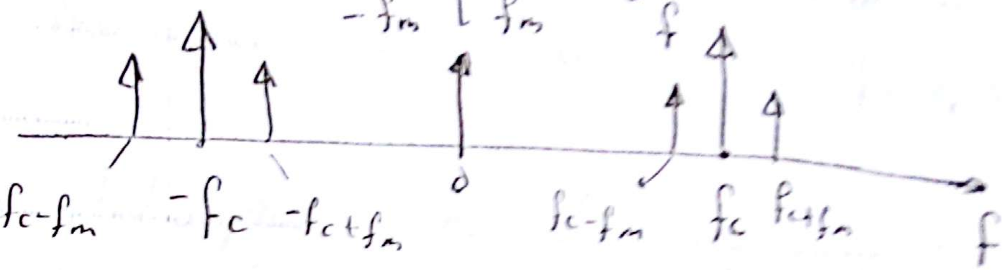
الا إذا ذكر خلاف ذلك

...pectrum of all signals at Superheterodyne Rx

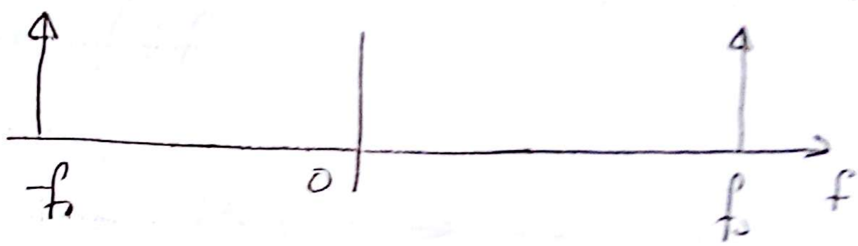
* m(t) ⟶ M(F)



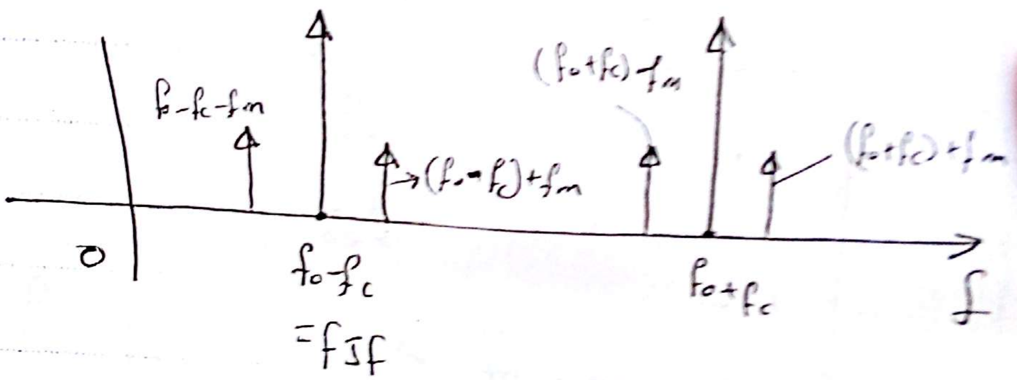
* AM Signal



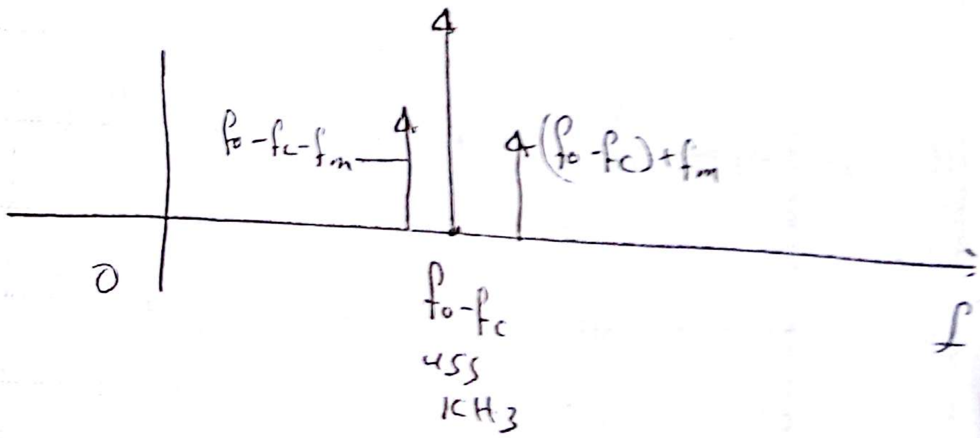
* Local oscillator f_o



* Mixer o/p
الزيادة اتطلع



* IF Amplifier o/p
الزيادة تختفي



* Detector o/p
m(t)

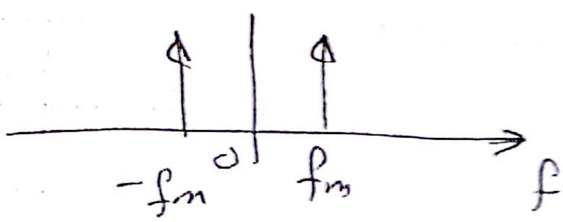


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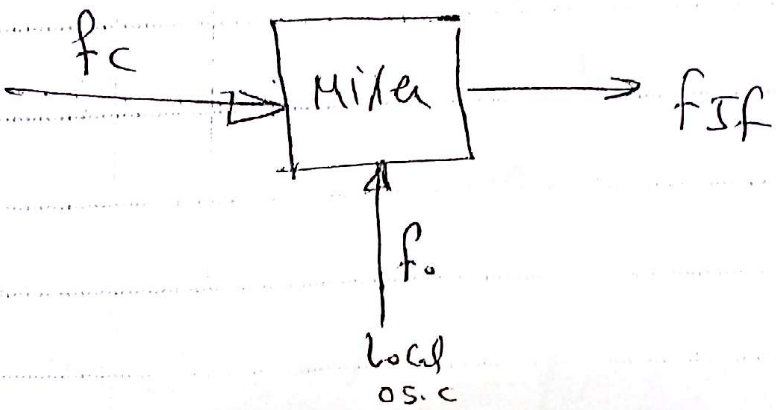
Image frequency

هي أي اشارة غير مرغوب فيها لها تردد معين عند Fimag
خلطه "MIX" مع ال local oscillator يعطي FIF

is any unwanted signal when it's frequency MIX with f_{Lo} give f_{IF}



$$F_{IF} = f_o - f_c \qquad \leftarrow f_o > f_c \text{ عند}$$

$$F_o = f_c + f_{IF}$$

ال f_o أعلى من f_c بـ f_{IF}

$$\boxed{F_{imag} = f_c + 2f_{IF}}$$

or $\boxed{F_{imag} = f_o + f_{IF}}$

صح؟

والسبب في ظهور تلك المشكلة هو استخدام poor tuned circuit "في أول مرحلة بعد ال Antenna"

up side Conversion

$f_o > f_c$

$f_{IF} = f_o - f_c$

$f_{imag} = f_c + 2f_{IF}$

$= f_o + f_{IF}$

Down side Conversion

$f_c > f_o$

$f_{IF} = f_c - f_o$ → الرمز

$f_{imag} = f_c - 2f_{IF}$

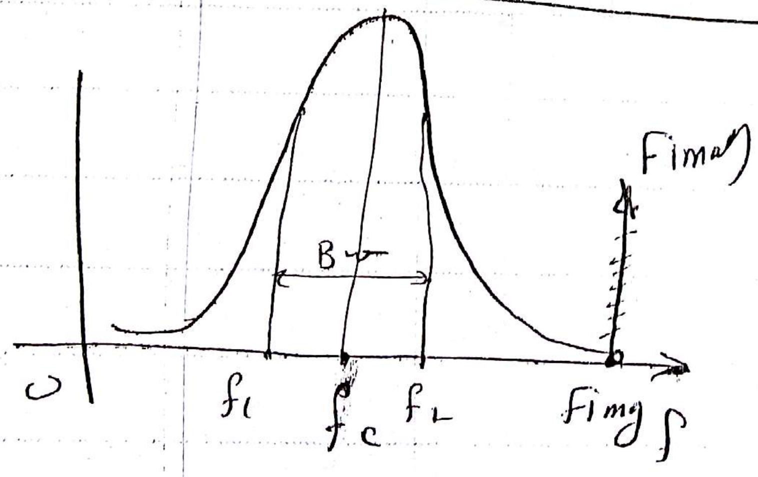
$= f_o - f_{IF}$

كل مشكلة ال image تم عمل narrow band tuned circuit

حيث ان يكون ال BW صغير حتى يمرر فقط ال f_c

ولا يمرر ال Image

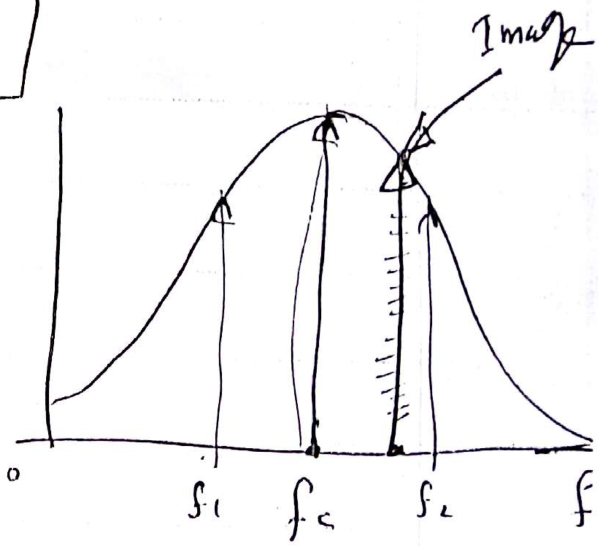
$$\boxed{\underset{\text{tuned circuit}}{BW} = \Delta f_{RF} < 2f_{IF}}$$



$BW = f_2 - f_1 = \Delta f_{RF} < 2f_{IF}$

هنا ال BW صغير ولم

تستطع ال Image ان تمر



$BW > 2f_{IF}$

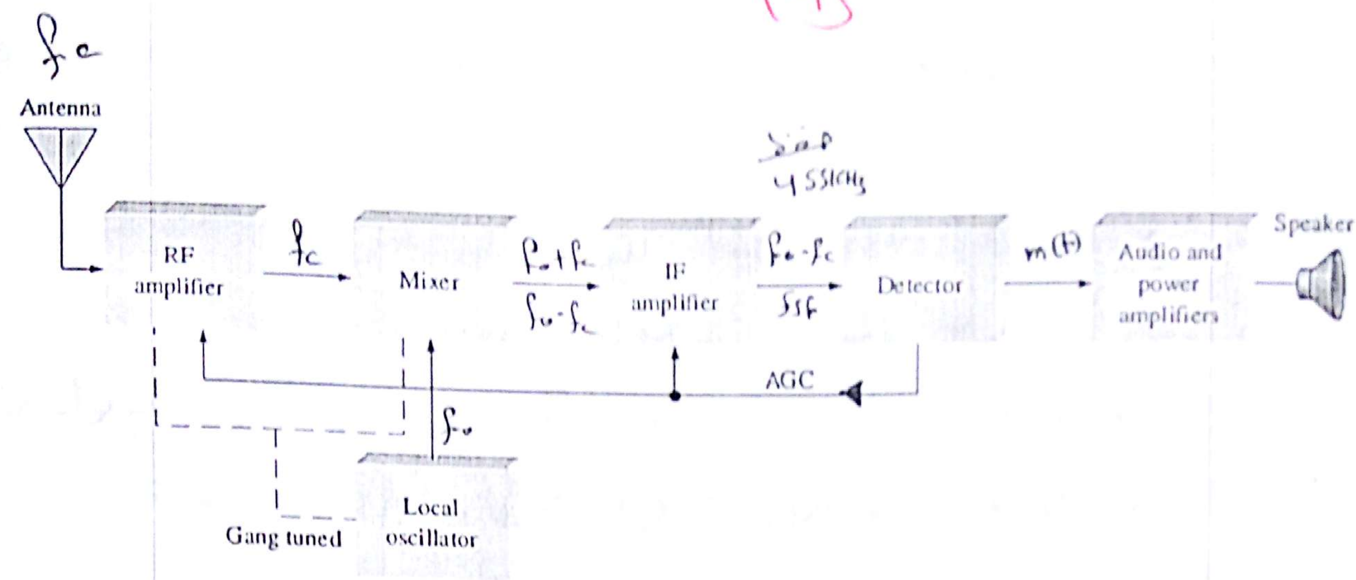
وبالتالي Fimage مرت من

ال tuned circuit

Scanned by CamScanner

③ Superhetrodyne Receiver

[4]



Main idea of operation

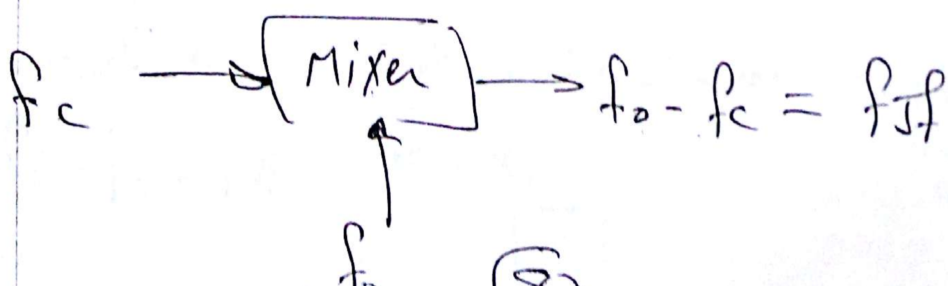
* the superhetrodyne RX takes the incoming radio frequency signal ~~and~~ (f_c) and transform it to fixed frequency Called intermediate frequency F_{IF}

$$F_{IF} = 455\ KHz \longrightarrow AM$$
$$F_{IF} = 10.7\ MHz \longrightarrow FM$$

مهم

* So we get fixed performance for all recieved signals

* يقوم بتحويل ترددات الاشارات المستقبلة (f_c) الى تردد ثابت
فقط F_{IF} وبذلك نضمن نفس الاداء لجميع الاشارات



(8)

ويتكون الـ Superhetrodyne Receiver من الأجزاء الآتية

* Antenna :⟹ يحول الإشارة الكهرومغناطيسية الى إشارة كهربية

① Rf Amplifier :

* عبارة عن high freq Amplifier يقوم بتكبير الإشارة المستقبلة f_c ومن ثم تستطيع أن نحسن الـ sensitivity

* كما أنه يحتوي على Variable Rf tuned Circuit حيث يتم بواسطته اختيار المحطة المطلوبة وعمل reject للمحطات الغير مرغوبة وبذلك يتم تحسين الـ selectivity

② Mixer ⟹

* يقوم بعمل mix لكلا من f_c , f_o وذلك للحصول على الفرق $|f_o - f_c|$ والمجموع $f_o + f_c$

* الهدف الرئيسي من الـ Mixer هو الفرق والذي $f_{IF} = f_o - f_c$ هو تردد ثابت وبالتالي يتم تحسين وتحسين الـ RX performance

③ Local oscillator

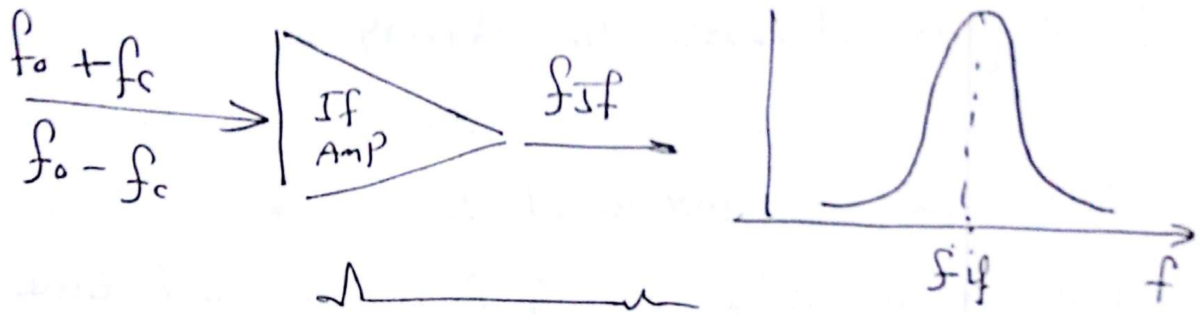
* هو عبارة عن Variable oscillator يقوم بإنتاج تردد f_o . والذي يتم عمل له Mix مع f_c

* يتم التحكم في كلا من الـ f_o والـ f_c الذي تم اختياره عن طريق الـ Rf tuned circuit في نفس الوقت بحيث يكون دائماً

$$f_o - f_c = f_{IF} = 455\ KHz$$

If Amplifier

- هو عبارة عن Amplifier لكى يكبر الإشارة وكذلك يحتوى على If filter كى يمرر التردد فقط ويزيد من الـ selectivity



⑤ Detector ⟹

⇐ عبارة عن envelope detector ومهمته إسترجاع الإشارة $m(t)$ مرة أخرى

⑥ Audio Amplifier →

⇐ مهمته هو رفع مستوى الباور فى الإشارة $m(t)$ حتى تستطيع تشغيل السماعة

⑦ Automatic Gain Control AGC

تقوم بالتحكم فى Gain كلاً من الـ If and Rf Amplifiers بحيث نفسه أن مستوى الإشارة الذى يصل الـ Detector ثابت وبالتالى تكون مستوى الإشارة للمحطات البعيدة هو نفسه للإشارات القريبة

Superhetrodyne AM Rx (lect 2)

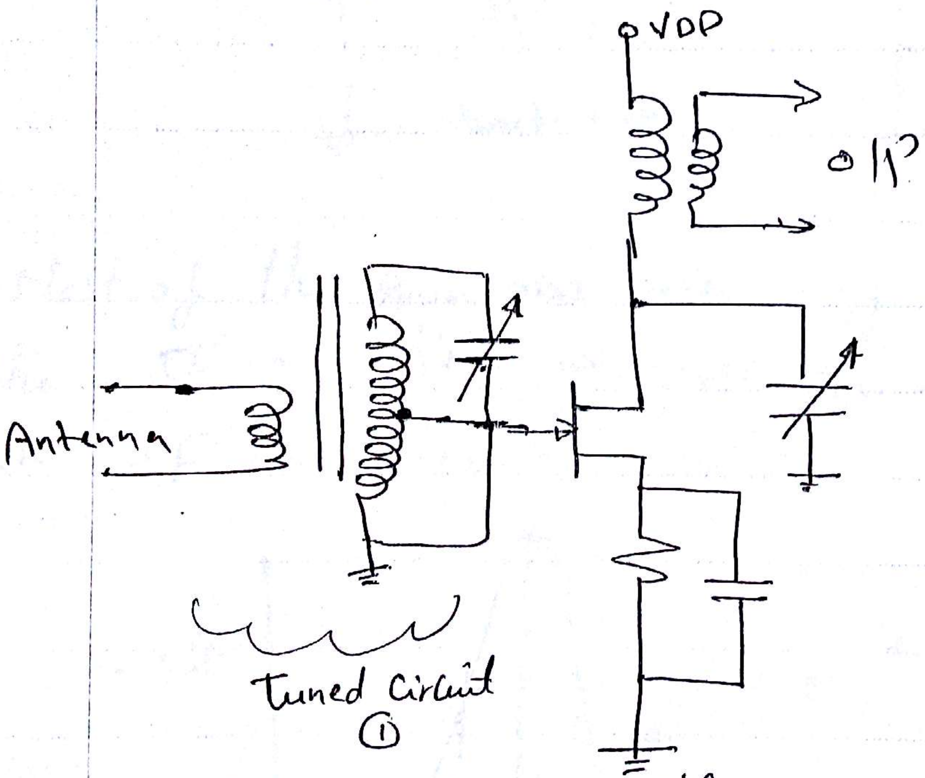
① **Rf amplifier** ⇒ Provide high gain to improve sensitivity.

⇒ Provide high selectivity using tuned circuit

⇒ Called Low noise amplifier (LNA)

⇒ Consist of class A power amplifier ⇒ for linearity.

⇒ Circuits Contain BJT or FET Transistor



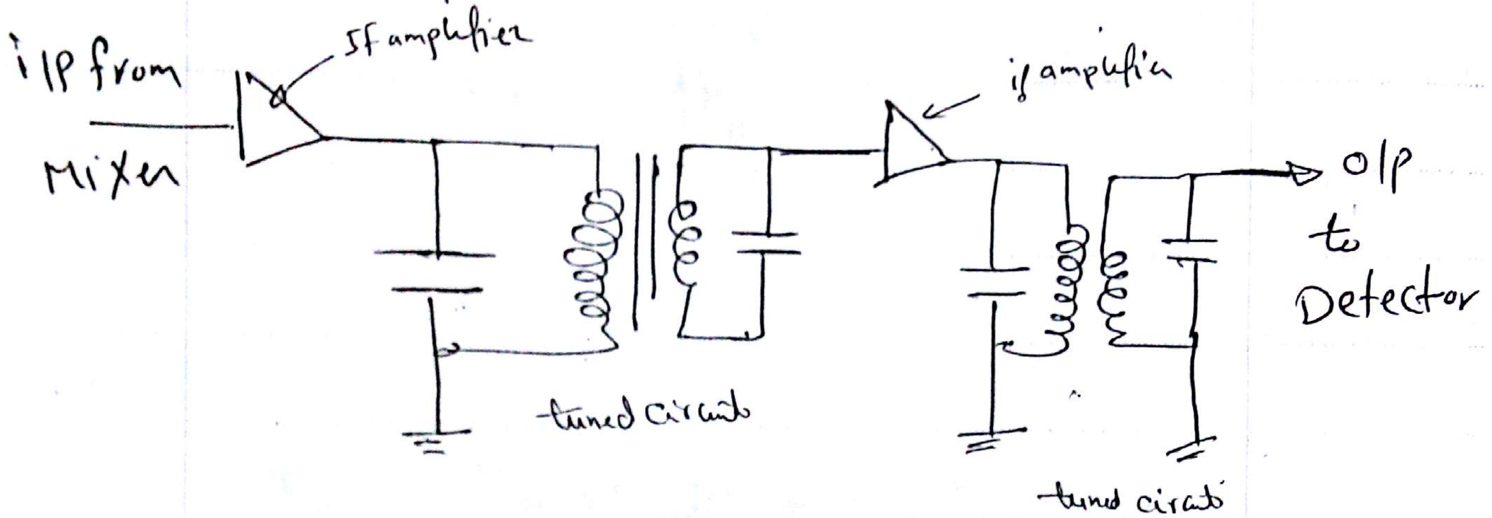
Class A Rf amplifier

لاحظ انه فى الدخل Tuned circuit متغيره لتمرير التردد المطلوب

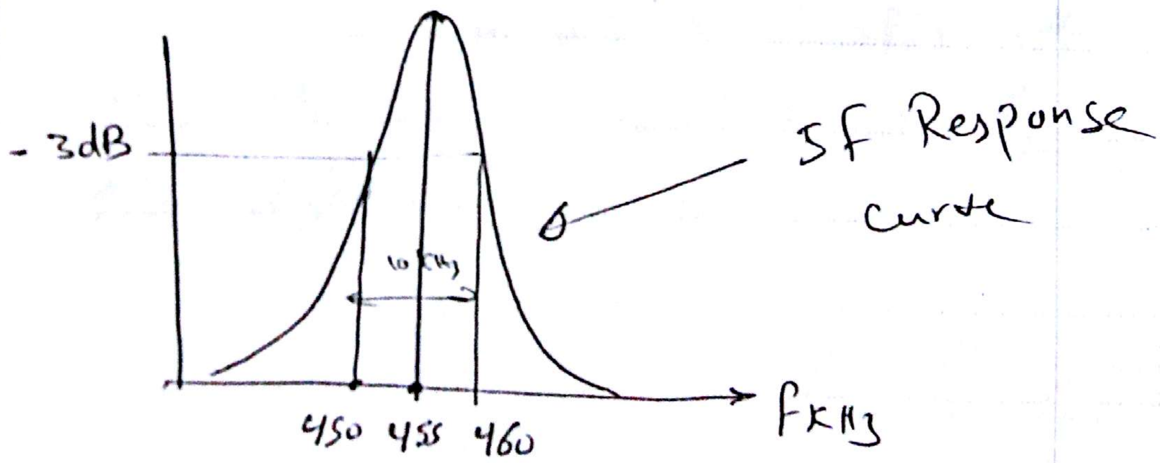
IF Amplifier :

* Respond only to 455KHz and any side frequencies lying in the 10kHz Bandwidth

⇒ has a tuned Circuit at it's i/p or o/p Centered at 455KHz with 10KHz BW



* Most of the gain and selectivity are produced by the IF amplifier ← so we use two or more IF amplifiers

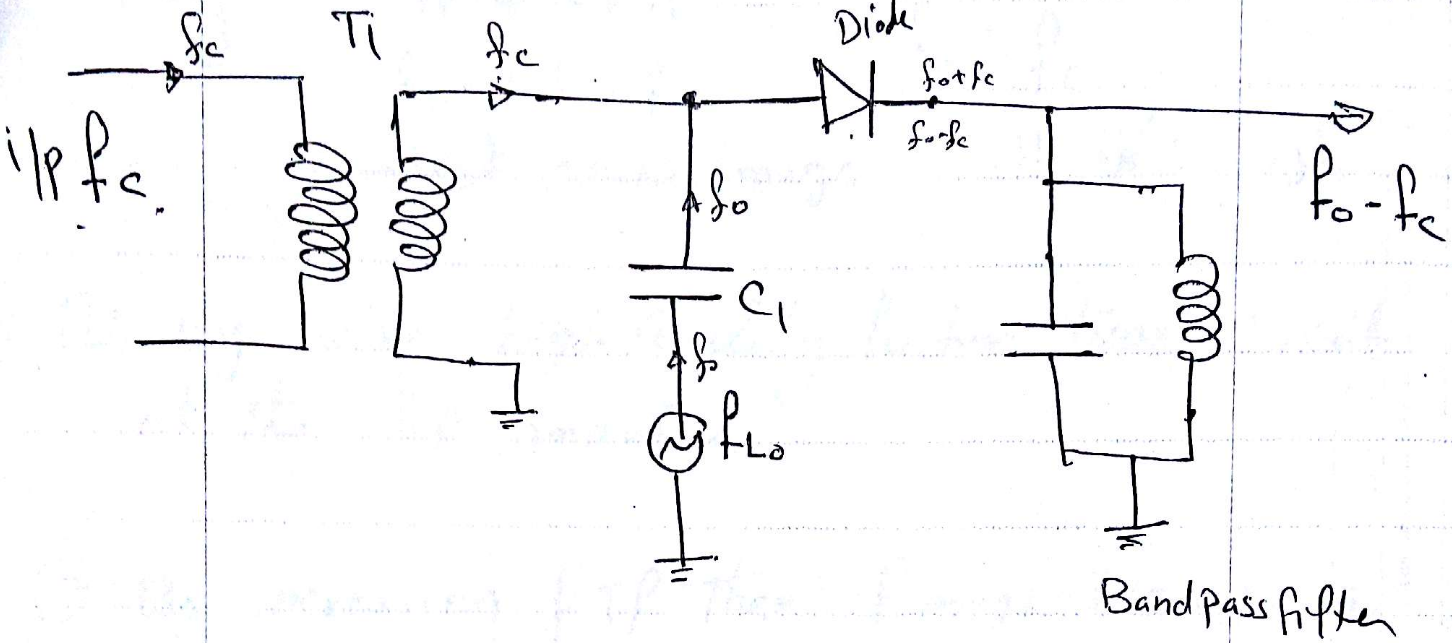


BW = 10KHz for AM

3) Mixer:

* أهم خاصية فيه هي الـ Nonlinearity

* أشهر الأنواع هو الـ Diode Mixer



* تم إدخال الـ f_c عن طريق الملف الابتدائي لـ T1

* // // الـ f_o // // الكاثف C_1

* تم جمع f_o و f_c عند دخل الـ Diode

* تقوم الـ Diode بعملية nonlinear حيث يكون خرجه هو (f_o+f_c) و (f_o-f_c)

* then the tuned circuit select only the difference f_o-f_c

Solving image Problem

$$f_{img} = f_c + 2f_{IF}$$
$$f_o + f_{IF} \quad , f_o > f_c$$

حل مشكلة ال image هناك طريقتان

(1) By using high quality factor tuned circuit at the Rf amplifier

(2) By increasing f_{IF} then fimage increase & حيث بزيادة f_{IF} يزيد fimg ويخرج خارج نطاق ال tuned circuit

* وهناك حل ثالث وهو افضل من الاثنين السابقين عن طريق استخدام ما يسمى

Dual-Conversion Receiver

* يتم فيه استخدام عدد (2) Mixer وعدد (2) Local oscillator

⇒ The first Mixer convert the incoming signal (f_c) to a high intermediate frequency F_{IF_1} to eleminate image

⇒ The second Mixer is to convert the first (F_{IF_1}) to lower fregency (F_{IF_2}) as shown in the figure

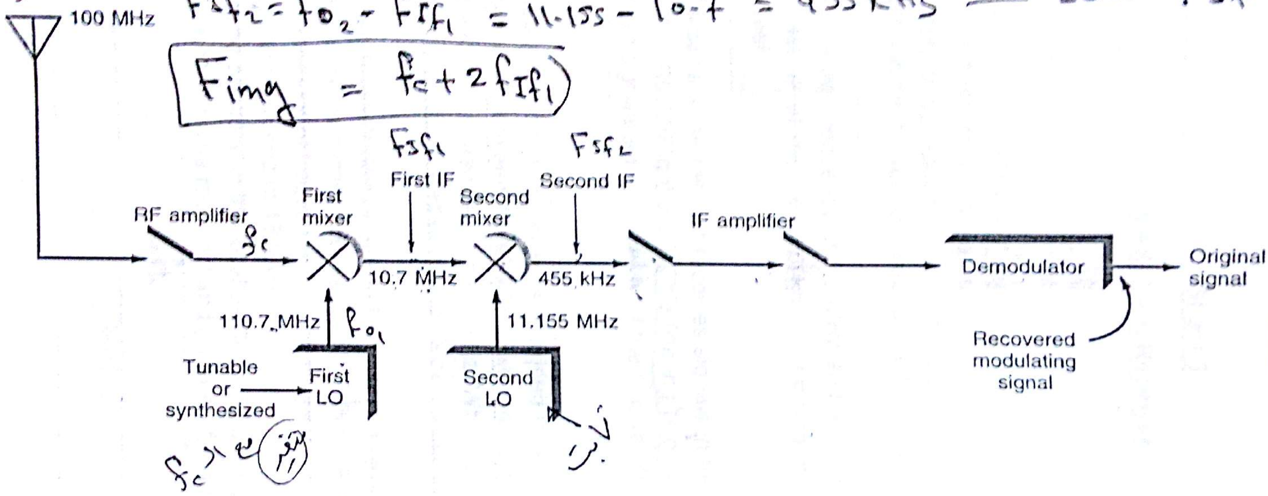
حتى تناسب ال Demodulator

Ex

$F_{IF_1} = f_{o_1} - f_c = 110.7 - 100\,MHz = 10.7\ MHz \rightarrow$ High f_{IF}

$f_{IF_2} = f_{o_2} - f_{IF_1} = 11.155 - 10.7 = 455\,KHz \Rightarrow$ Low f_{IF}

$$\boxed{F_{img} = f_c + 2f_{IF_1}}$$



A dual-conversion superheterodyne

ملحوظة ① f_{o1} تتغير مع ال Rf tuned circuit يعني بتتغير على حسب ال f_c اللي بتستقبله

② f_{o2} ثابت لأن f_{IF_2} و F_{IF_1} ثوابت

③ F_{img} تأتي فقط من أول مرحلة " $f_c + 2f_{IF_1}$ "

Sheet 3

BASIC Am Receiver

1. The input to a certain AM receiver consists of a 1500 kHz carrier and two side frequencies separated from the carrier by 20 kHz. Determine the frequency spectrum at the output of the mixer amplifier and determine the frequency spectrum at the output of the IF amplifier.

2. For a carrier frequency of 1.2 MHz and a modulating frequency of 8.5 kHz, list all of the frequencies on the output of the mixer in an AM receiver.

3. Consider a superhet that receives signals in the 50-54MHz range with $f_{lo}=f_c+f_{IF}$. Assuming there is little filtering prior to the mixer, what range of input signals will be received if the f_{IF} is (a) 455 kHz. (b) 7MHz.

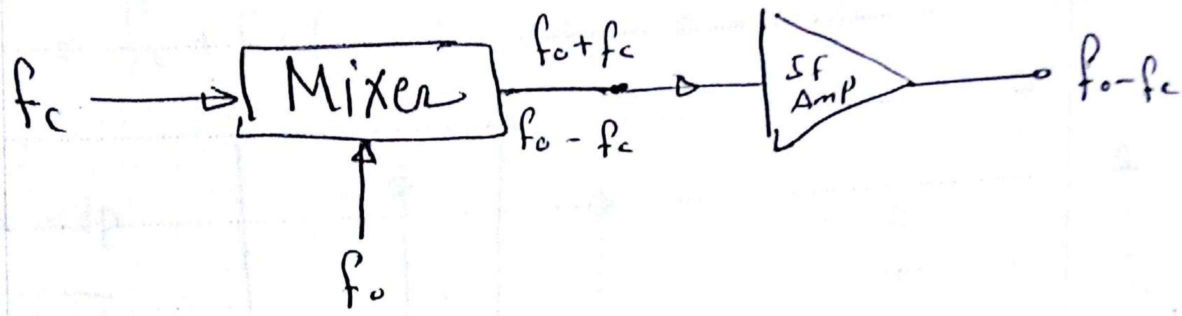
4. A superheterodyne receiver is designed to receive signals with carrier frequencies between 4 and 6 MHz with transmitted bandwidths of 100 kHz each. Its IF frequency is 850 kHz. What range of local oscillator frequencies is required using high-side injection ($f_{LO} > f_c$) ?

5. A radio receiver used in the AM system is shown below. The mixer Translates the carrier frequency fc to a fixed IF of 455 kHz by using a local oscillator of frequency f_{LO}. The broadcast-band frequencies range from 540kHz to 1600kHz. Determine the range of tuning that must be provided in the local oscillator (i) when f_{LO} is higher than fc (superheterodyne receiver) and (ii) when f_{LO} is lower than fc.

Sheet 3 - AM Rx

[1] $f_c = 1500\ KHz$ $\quad f_m = 20\ KHz$

SoL

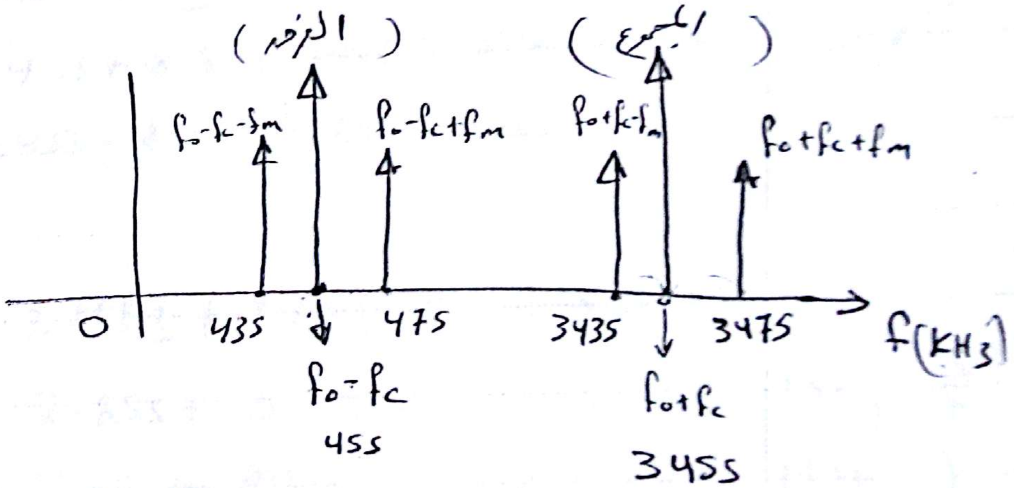


Let $f_{IF} = 455\ KHz$

$$f_o = f_c + f_{IF} = 1500 + 455 = 1955\ KHz$$

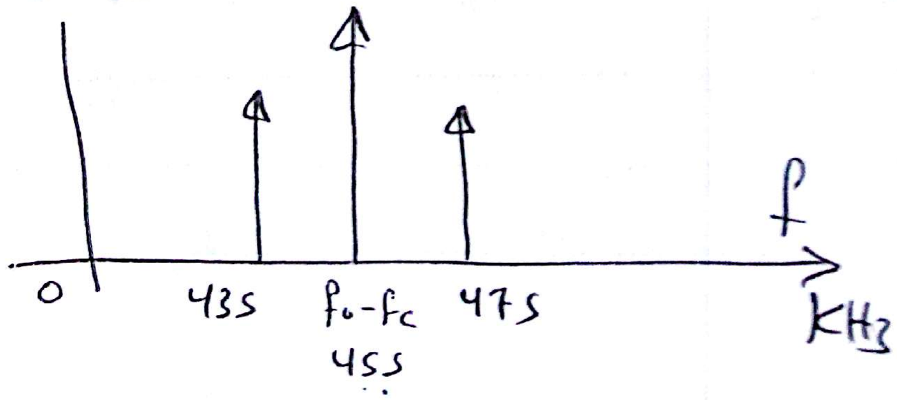
At Mixer o/p

الرئيسي + الفرعي



At IF Amp o/p

" الرئيسي " فقط



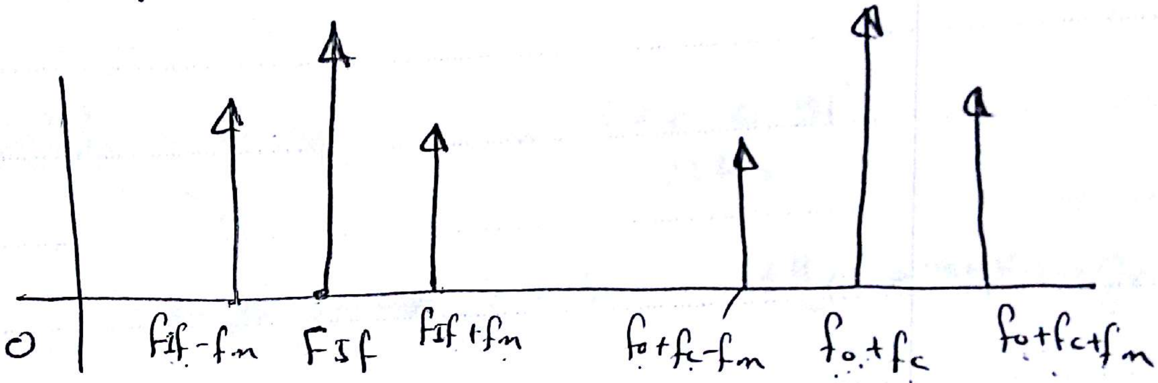
$f_c = 1.2\,MHz \qquad f_m = 8.5\,KHz$

SoL

Let $f_{IF} = 455\,KHz$

$$f_o = f_c + f_{IF} = 1.2\,MHz + 0.455\,MHz = 1.655\,MHz$$

<u>Mixer o/p</u>



1) $F_{IF} = 455\,KHz = f_o - f_c$

2) $F_{IF} + f_m = 455 + 8.5 = 463.5\,KHz$

3) $f_{IF} - f_m = 455 - 8.5 = 446.5\,KHz$

الغرض

4) $f_o + f_c = 1.2\,MHz + 1.655 = 2.855\,MHz$

5) $f_o + f_c + f_m = 2.855 + 8.5\,KHz = 2.8635\,MHz$

6) $f_o + f_c - f_m = 2.855 - 8.5\,KHz = 2.8465\,MHz$

الأخرى

$f_c = (50 - 54\ MHz)$ ← little filter ⇒ image

يعني bad tuned circuit

Sol

ⓐ $f_{IF} = 455\ KHz$

$F_{Imag} = f_c + 2f_{IF} = (50 \rightarrow 54) + 2 \times 455\ KHz$

$= (50 + 0.91)\ MHz \longrightarrow (54 + 0.91)\ MHz$

$= 50.91 \longrightarrow 54.91\ MHz$ → image range

∴ New Range of Recieved signal $(50 \longrightarrow 54.91)\ MHz$

ⓑ for $F_{IF} = 7\ MHz$

$F_{Imag} = f_c + 2f_{IF} = (50 \rightarrow 54) + 2 \times 7$

$= 50 + 14 \longrightarrow 54 + 14$

$= 64 \longrightarrow 68\ MHz$ → image range

∴ the Range of i/p signal $(50 \rightarrow 68)\ MHz$

$f_c = (4 \rightarrow 6)$ MHz , $f_m = 100$ KHz , $f_{IF} = 850$ KHz

Sol

for high side injection ($f_{Lo} > f_c$)

$$f_o = f_c + f_{IF}$$

$$= (4 \rightarrow 6) + 850 \text{ KHz}$$

$$f_o = 4.85 \rightarrow 6.85 \text{ MHz}$$

$f_{lo} = ??$

5) $F_{IF} = 455$ KHz

$f_c = (540 \rightarrow 1600)$ KHz

Sol

(a) for $f_{Lo} > f_c$

$$f_{lo} = f_o = f_c + f_{IF} = (540 \rightarrow 1600) + 455$$

$$f_o = (540 + 455 \rightarrow 1600 + 455)$$

$$f_o = (995 \rightarrow 2055) \text{ KHz}$$

(b) for $f_o < f_c$

$$f_o = f_c - f_{IF} = (540 - 455) \rightarrow (1600 - 455)$$

$$f_o = (85 \text{ KHz} \rightarrow 1145 \text{ KHz})$$

Sheet 4

1. A superheterodyne receiver must cover the range from 220 to 224 MHz. The first IF is 10.7 MHz; the second is 1.5 MHz. Find (*a*) the local oscillator tuning range, (*b*) the frequency of the second local oscillator, and (*c*) the first IF image frequency range.
(Assume a local oscillator frequency higher than the input by the IF.)

(Sol)

i) 220+10.7 =230.7MHz

224+10.7 =234.7MHz

Tuning range=> 230.7 to 234.7 MHz

ii) 2^{nd} LO = 1.5 MHz higher than the !st IF

Therefore freqof 2^{nd} LO = 10.7 +1.5 =12.2 MHz

iii) 230.7 +10.7 = 241.4 MHz

234.7 +10.7 = 245.4 MHz :

The first IF image frequency range. => 241.4 – 245.4 MHZ

==

2. A dual-conversion superhet has an input frequency of 62 MHz and local oscillators of 71 and 8.6 MHz. What are the two IFs?

(SoL)

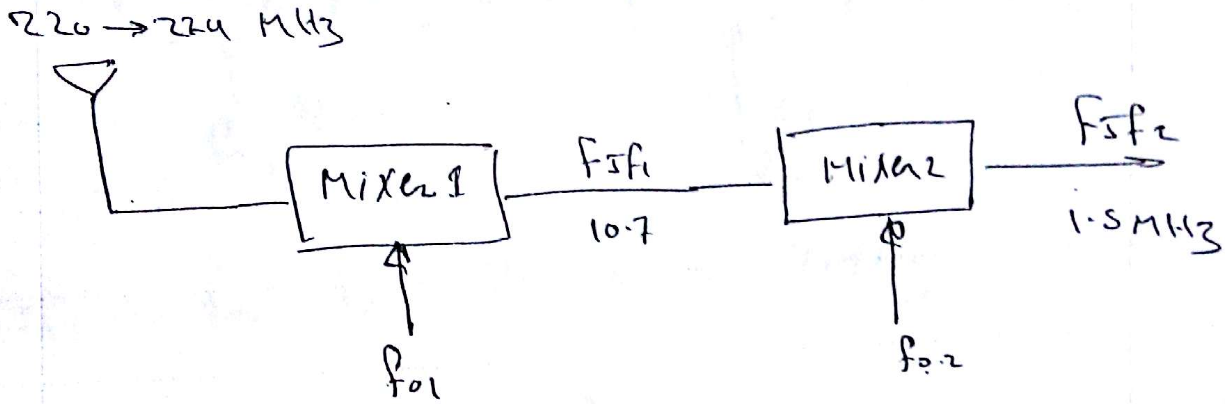
The products of the mixers can be the sum or the difference between the local oscillators and the signal. It is more likely though that the first IF is 71-62 = 9MHz and the second IF is 9-8.6 = 400kHz.

Sheet (4) Dual Conversion

(1) $f_c = (220 \rightarrow 224)$ MHz , $F_{IF_1} = 10.7$ MHz

$F_{IF_2} = 1.5$ MHz

Sol



(a) $\because f_{o_1} = f_c + f_{IF_1} \Rightarrow f_{o_1} = (220 \rightarrow 224) + 10.7$

$f_{o_1} = 220 + 10.7 \longrightarrow 224 + 10.7$

$f_{o_1} = (230.7 \longrightarrow 234.7)$ MHz $\Longrightarrow$ (a)

(b) $f_{o_2} = f_{IF_1} + f_{IF_2} = 10.7 + 1.5 = 12.2$ MHz $\rightarrow$ (b)

~~FIf1~~ (c) $F_{imag} = f_c + 2F_{IF_1} = (220 \rightarrow 224) + 2 * 10.7$

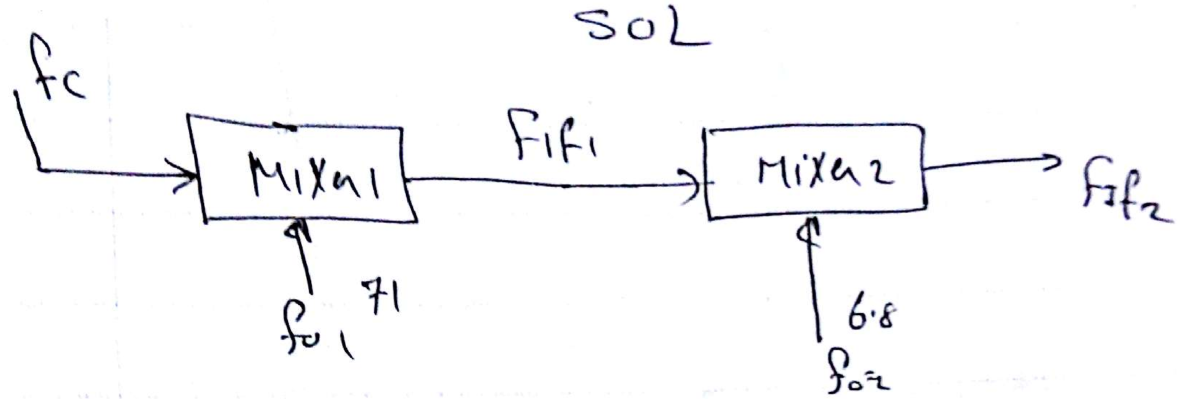
$= f_{o_1} + 2 f_{IF_1}$

$F_{img} = (241.4 \longrightarrow 245.4)$ MHz $\Longrightarrow$ (c)

sheet (4)

$f_c = 62\ MHz \qquad f_{o1} = 71\ MHz \qquad f_{o2} = 8.6\ MHz$

SOL



$F_{IF_1} = f_{o1} - f_c = 71 - 62 = 9\ MHz$

$f_{IF_2} = f_{o2} - f_{IF_1} = f_{IF_1} - f_{o2} \Longrightarrow$ المهم الرقم
لبغض النظر عن الاشارة

$f_{IF_2} = |f_{o2} - f_{IF_1}| = |(6.8 - 9)| = 400\ KHz$

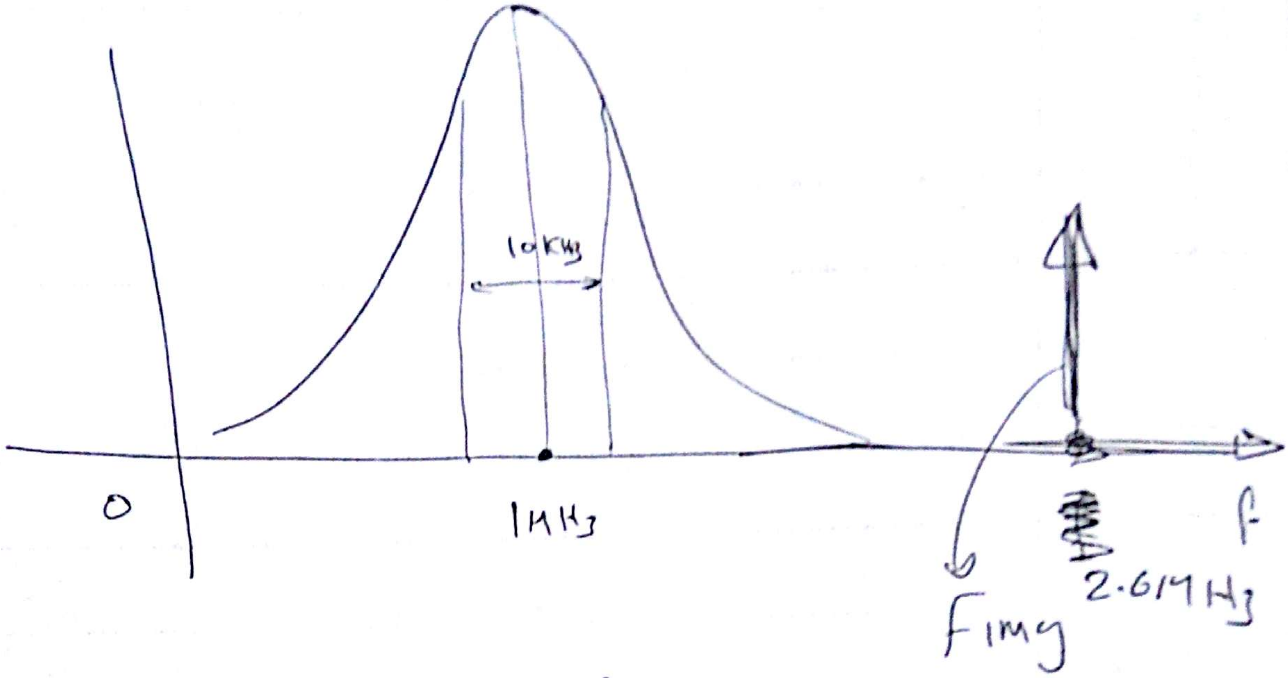
ملحوظ

باستخدام ال Dual Conversion لاحظنا أن أول (F_{IF_1})
قد زادت قيمته وبالتالي سوف يكون خارج نطاق ال
Bw of the Rf tuned circuit.

EX Let Bw of tuned circuit is 10 KHz at Center frequency of 1 MHz , $f_{IF_1} = 800\ KHz$, $f_{IF_2} = 455\ KHz$. Then $f_{img} = f_c + 2f_{IF_1} = 1 + 2 \times 800$
$= 2.6\ MHz$

Sheet (4)

$F_{img} = 2.6\,MHz$



بعيد خالص عن نطاق ال tuned circuit

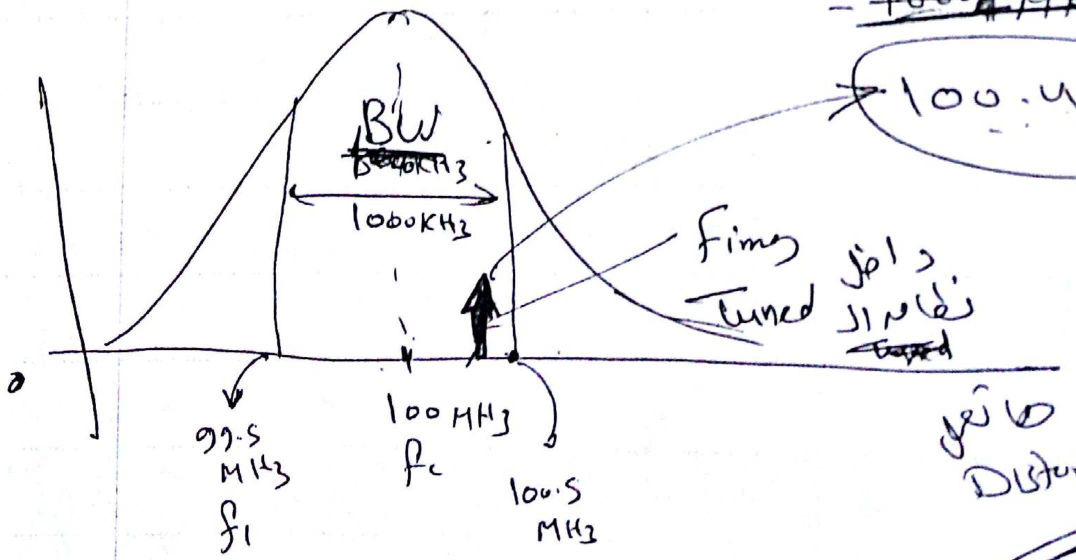
Ex 8 let $f_c = 100\,MHz$, $f_{IF} = 200\,KHz$

, $BW = 1000\,KHz$

$\therefore F_{img} = f_c + 2f_{IF} = 100\,MHz + 2 \times 200\,KHz = 100.4\,MHz$

$= \cancel{100.4\,MHz}$

$100.4\,MHz$

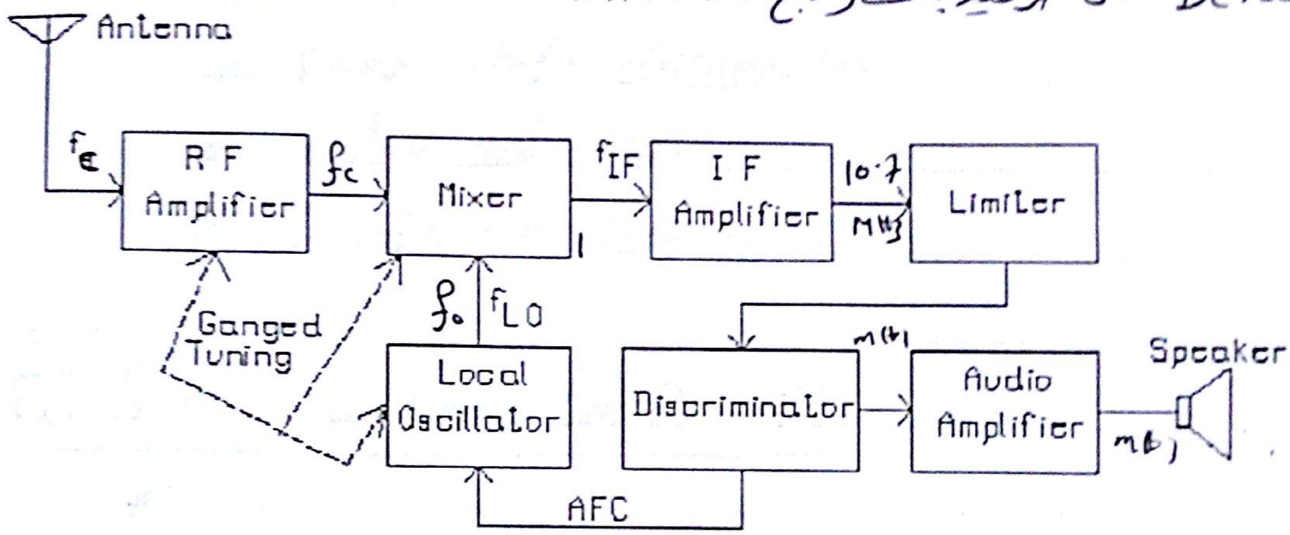


هتعمل Distortion

$\boxed{3}$

FM Receiver

ويشبه كثيراً ال AM Receiver ولكن تكون الاختلاف في مرحلة ال Detector أي طريقة إسترجاع ال m(t)



limiter : used to remove noise from Fm signal.

AFC : Automatic frequency Control

وهو يستخدم لضبط تردد ال f_o من ال Local oscillator وكذلك ضبط ال RF tuned Circuit عند تردد المحطة المطلوبة لأنه أحياناً يحدث عملية drift للإشارة المستقبلة نتيجة تأثير الحرارة على المكونات الالكترونية

Difference between AM and FM Spectrum

	AM	FM
1) Range	540 KHz → 1600 KHz	88 MHz → 108 MHz
2) F_{If} خفف	455 KHz	10.7 MHz
3) BW or Carrier separation	10 KHz	200 KHz

FM Demodulators :-

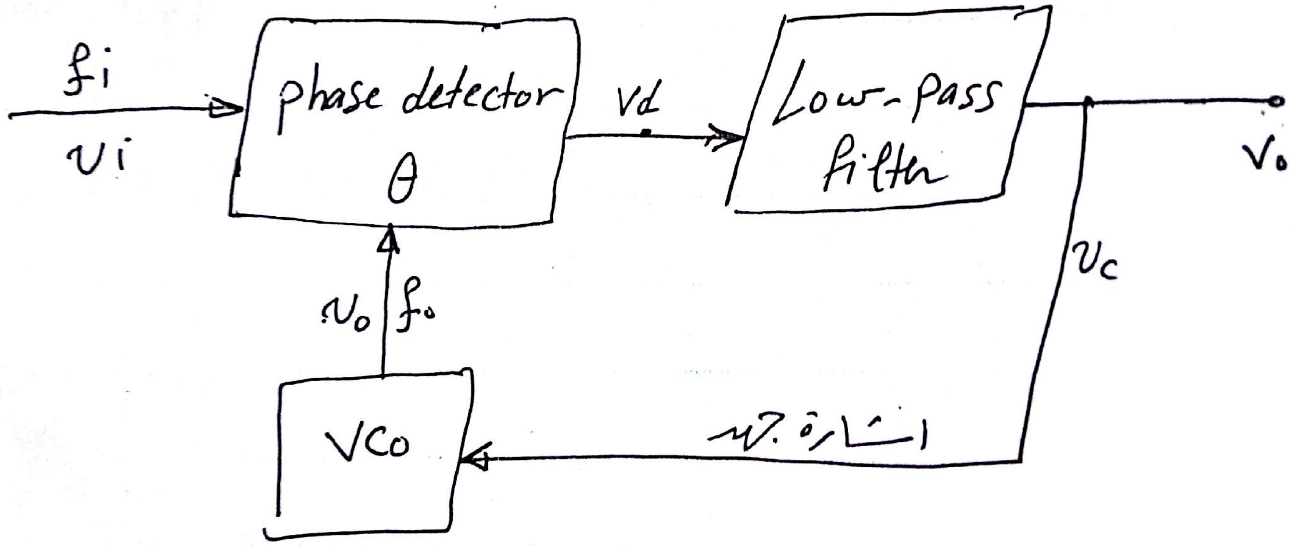
1. phase locked loop (PLL)
2. slope detection
3. phase shift discriminator
4. Ratio detection
5. Quadrature detection

[1] Phase locked loop PLL

*

* is feed back Circuit Consist of

ⓐ phase detector ⓑ Low pass filter ⓒ VCo.



* فكرة العمل هي جعل ال f_o من ال VCo متزامن مع ال f_i مهما تتغير حيث أنه عندما يكون هناك خطأ في ال phase بين ال f_o , f_i [illegible] أنهم مختلفين في التحديد عندما يزيد أو يقل خرج ال phase Detector والذي بدوره يغير في تردد ال VCo حتى يتساوى مع تردد ال f_i

Phase detector :-

⇐ هو عبارة عن دائرة تقوم بعملية multiplication كلاً من v_i & v_o

* let

$$v_i = V_i \sin(2\pi f_i t + \theta_i) \rightarrow \text{i/p signal}$$

$$v_o = V_o \sin(2\pi f_o t + \theta_o) \rightarrow \text{From VCO}$$

$$v_d = v_i * v_o \Rightarrow \text{phase detector o/p}$$

$$v_d = V_i \sin(2\pi f_i t + \theta_i) * V_o \sin(2\pi f_o t + \theta_o)$$

& let $f_i = f_o \Rightarrow$ Locking.

$$v_d = \frac{V_i V_o}{2}\Big[\underbrace{\cos(\theta_i - \theta_o)}_{\text{الفرق}} - \underbrace{\cos(4\pi f_i t + \theta_i + \theta_o)}_{\text{المجموع}}\Big]$$

After LPF

$$v_c = \frac{V_i V_o}{2} \cos(\theta_i - \theta_o) \qquad \because (\theta_i - \theta_o) = \theta_e$$

$$\boxed{v_c = \frac{V_i V_o}{2} \cos\theta_e}$$ مهم

& $\theta_e = \theta_i - \theta_o$

where

v_c :- Control signal from LPF which feed back to VCO to Control its frequency

θ_e : Phase error

v_o = VCO o/p يتناسب ع // proportional to phase difference θ_e

∴ f_o from VCO depend on θ_e

Locking

Locking ⇐ معناها إن الـ VCO قدر يطلع نفس تردد الـ f_i

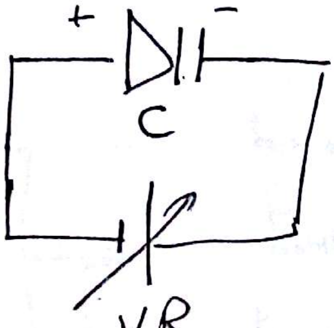
(b) VCO

⇐ هو المسئول عن إخراج الـ f_o

⇐ ممكن إستخدام أي نوع من الـ Variable oscillator

⇐ أشهر الأنواع هو المستخدم به Varactor diode

- والذي فيه يتم التحكم في f_o عن طريق جهد عكسي يتم تطبيقه على الـ Varactor diode والذي بالتالي يقيد في سعته وبالتالي أصبح لدينا مكثف متغير مع الـ V_R العكس



$V_R \uparrow\uparrow \Rightarrow C \downarrow\downarrow$

وبالتالي ممكن وضع الـ Vractor diode في أي دائرة Osillator كمكثف متغير ... وبالتالي نستطيع التحكم في تردد الخرج

where

$$f_o = \frac{1}{2\pi RC} \quad \text{or} \quad f_o = \frac{1}{2\pi\sqrt{LC}}$$

ع حسب شكل الدائرة

∴ when V_R « Reverse voltage » increase then the Capacitance decrease and f_o increase

$$V_R \uparrow\uparrow \Rightarrow C \downarrow\downarrow \Rightarrow f_o \uparrow\uparrow$$

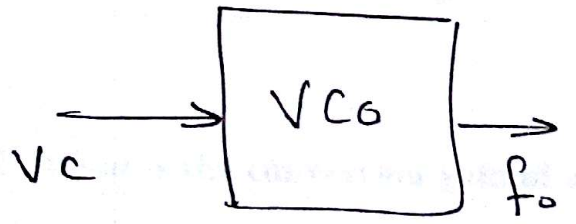
$$f_o = \frac{1}{2\pi RC}$$

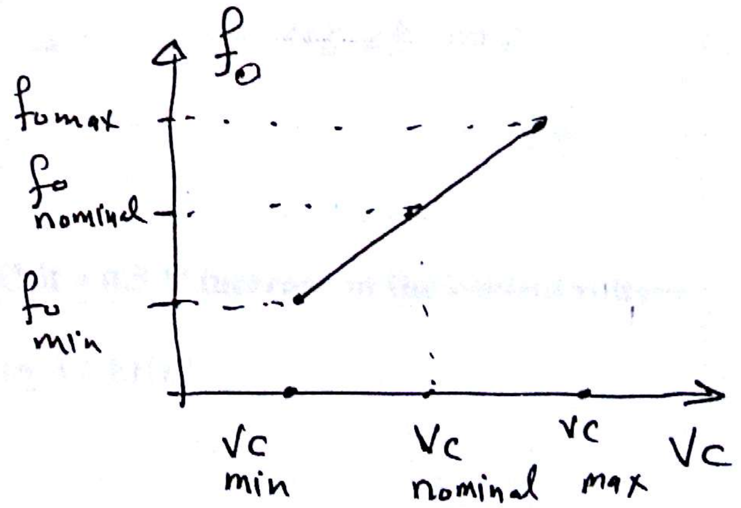
$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

⇒ Conversion gain K

$$K = \frac{\Delta f_o}{\Delta V_c} \qquad KHz/V$$

عباره عن مقدار التغير في تردد ال Vco نتيجه التغير
في جهد المسلط عليه « Control volt »





nominal = (nom) ⟹

هي عباره عن الحاله الاصليه بديهيه أو الاعتياديه
او المتوسط : اي خرج ال Vco بدون زيادة أو نقصان ال V_c

Sheet5

1. A PLL is locked onto an incoming signal with peak amplitude of 250 mV and a frequency of 10 MHz at a phase angle of 30° .The 400 mV peak VCO signal is at a phase voltage being fed back angle of 15°.

(a) What is the VCO frequency?

(b) What is the value of the control to the VCO at this point?

SOL

$f_i = 10 MHz$ $\theta_i = 30°$

$V_i = 250 mV$ $\theta_o = 15°$ $V_o = 400 mV$

a) Since PLL is Locked $\therefore f_i = f_o = 10 MHz$

b) $\because V_c = \frac{V_i V_o}{2} \cos\theta_e$ & $\theta_e = \theta_i - \theta_o = 30 - 15 = 15°$

$$\therefore V_c = \frac{250 \times 10^{-3} \times 400 \times 10^{-3}}{2} \cos 15° = 48.29 mV$$

2. What is the conversion gain of a VCO if a 0.5 V increase in the control voltage causes the output frequency to increase by 3.6 kHz?

SOL

$\Delta V_c = 0.5 V$ & $\Delta f_o = 3.6 KHz$

$$\therefore K = \frac{\Delta f_o}{\Delta V_c} = \frac{3.6 \times 10^3}{0.5} = 7.2 KHz / V$$

3. If the conversion gain of a certain VCO is 1.5 kHz per volt, how much does the frequency change if the control voltage increases 0.67 V?

SOL

$K = 1.5\ kHz / V$, $\Delta f_o = ??$ $\Delta V_c = 0.67\ V$

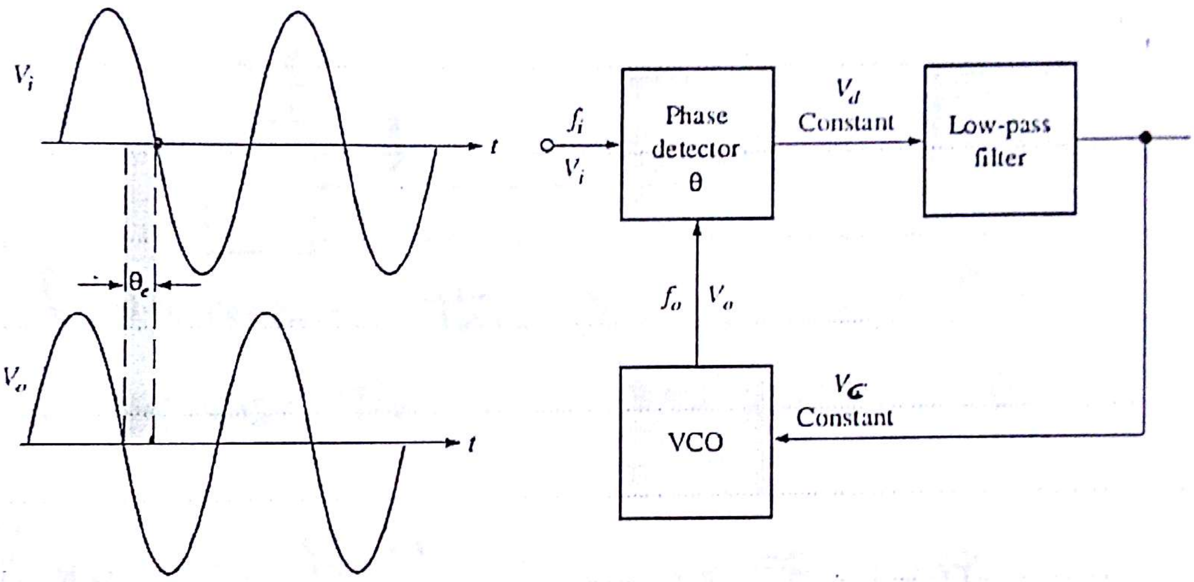
$\because K = \frac{\Delta f_o}{\Delta V_c} \Rightarrow \Delta f_o = K \cdot \Delta V_c$

$\Delta f_o = 1.5 * 0.67 = 1.005\ kHz$

Basic PLL operation

Case 1- $f_i = f_o$, $\theta_i \neq \theta_o$

- Two sinusoidal signals of the same frequency but with a phase difference,
- For this condition the PLL is in lock and the VCO control voltage is constant.



عندما تكون $f_i = f_o$ وكان $\theta_i \neq \theta_o$

تكون الفرق بين θ_i ، θ_o ثابت وبالتالي

$$\theta_e = \theta_i - \theta_o = \text{Constant}$$

$$\therefore V_c = \text{Constant}$$

$\therefore$ PLL is Locking

Case 2- **If f_i decreases.** (if $f_i < f_o$)

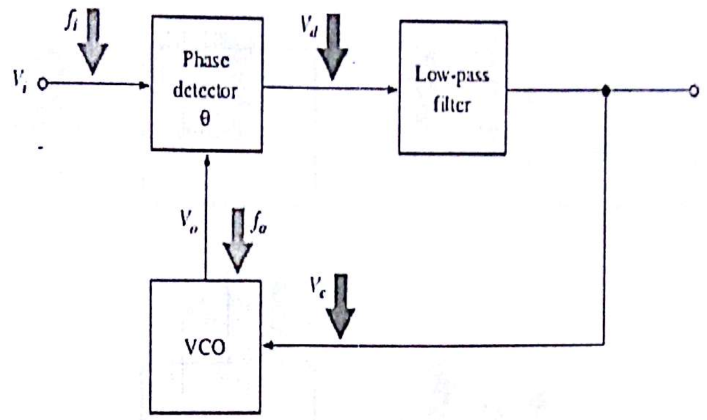
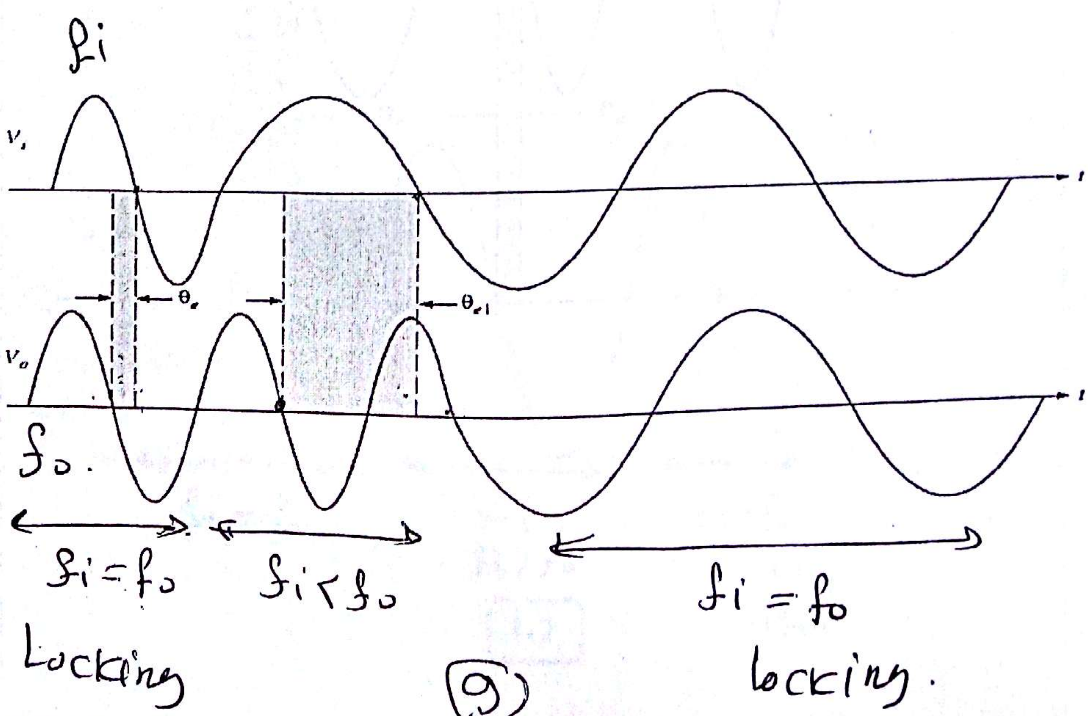


FIGURE 19–44
PLL action when f_i decreases.

when f_i decreases then θ_e increases to θ_{e1} then V_c decrease then f_o decrease until $f_o = f_i$

$\therefore f_i \downarrow\downarrow \Rightarrow \theta_e \uparrow\uparrow \Rightarrow V_c \downarrow\downarrow \Rightarrow f_o \downarrow\downarrow$

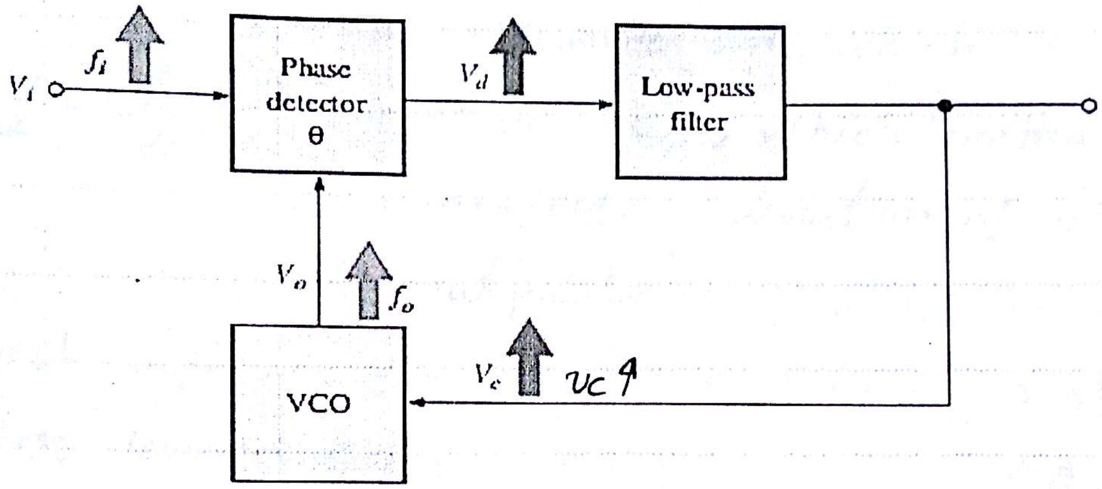
من الشكل التالي نلاحظ أنه عندما قلت قيمة f_i بشكل مفاجئ
فإن قيمة الـ θ_e زادت وبالتالي يقل الـ V_c والذي بدوره يقلل
من الـ f_o حتى تتساوى مع الـ f_i



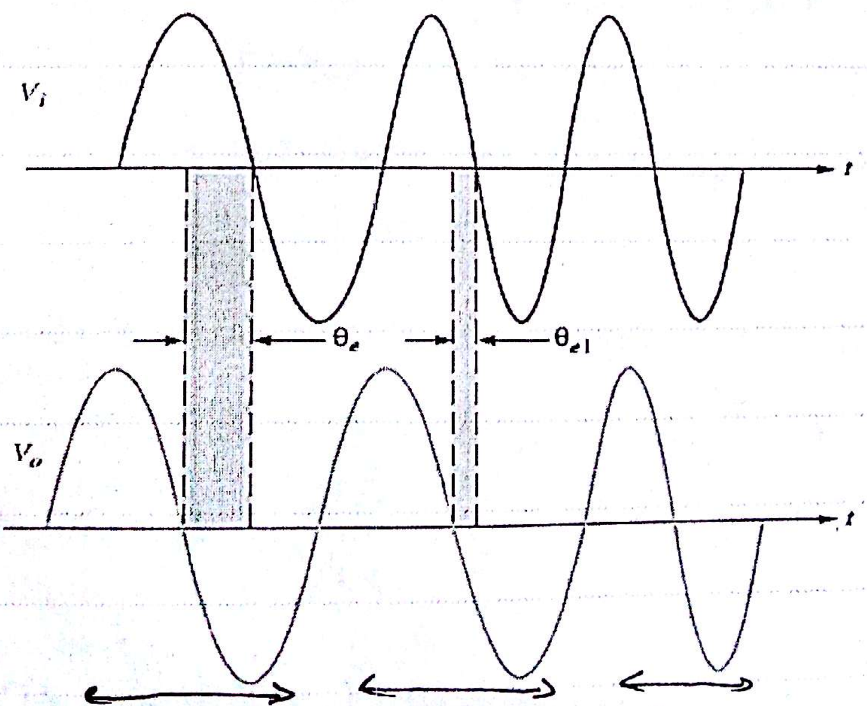
(9)

Case 3- If f_i increase $f_i > f_o$

nen f_i increase ⇒ θ_e will decrease to θ_{e1} which inturn increase v_c « VCo Control voltage » then f_o increase untill $f_o = f_i$ Locking



∴ $f_i \uparrow \Rightarrow \theta_e \downarrow \Rightarrow v_c \uparrow\uparrow \Rightarrow f_o \uparrow\uparrow \Rightarrow f_o = f_i$ = Locking



تعريفات هامه

, Lock Rang:

$$f_{Lock} = \pm \frac{8 f_o}{V_{CC}}$$

⇒ During locking ($f_i = f_o$) is the range of frequencies over which the PLL can maintain Lock, which limitted by

i) max frequency deviation of VCO

ii) output limits of phase detector

⇐ أثناء عمليه ال Locking هو مدى الترددات الذى تستطيع ال PLL خلاله المحافظه على عمليه ال Lock ويعتمد على :

i) max freq deviation of VCO

ii) output of phase detector

2) Capture Range

Assuming PLL not Lock is the range of frequencies over which the PLL can acquire « تحصل على » Lock with the incoming signal.

هو مدى الترددات الذى تستطيع ال PLL تحقيق عمليه ال Lock مع الاشاره القادمه f_i

$$f_{Lock} = \pm \frac{8 f_o}{V_{CC}}$$

f_o : free running frequency of VCO

V_{CC} : total supply voltage between +ve and −ve supply.